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PATENT APPLICATION
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METHOD FOR DESIGNING NEARLY CIRCULARLY SYMMETRIC DESCREENING FILTERS THAT CAN BE EFFICIENTLY IMPLEMENTED IN VLIW (VERY LONG INSTRUCTION WORD) MEDIA PROCESSORS

FIELD OF THE INVENTION

The present invention generally relates to the field of image processing and, more particularly, to the field of document and image rendering.

BACKGROUND OF THE INVENTION

When dealing with scanned color images, as with scanned monochrome images, one often has to apply a low pass filter to render a scanned image on a printer so that moiré is eliminated. This is done by descreening. The preferred way of descreening is with a circularly symmetric filter so that the same frequency occurring at any angle is descreened by approximately the same amount. A circularly symmetric response is easily achieved using a single, non-separable filter. However, it takes significantly more processing of the image data to apply a non-separable filter to image data than it does to apply a separable filter.

What is needed in this art is an application that achieves a close approximation to the desired circularly symmetric shape while requiring less processing power than is required to implement a non-separable filter.

BRIEF SUMMARY OF THE INVENTION

A method is disclosed for designing two separable filters, ***LPP*** & ***HPP***, that, when applied in sequence with a subtraction step, approximates the circularly symmetric frequency response achievable using a non-separable filter. The method of the present invention comprising: First, (a) selecting a cut-off frequency and designing therefrom a 1-D low pass filter **LP** such that: **LP** = [X_{-n}, $X_{-(n-1)}$, ... X_0, ... X_{n-1}, X_n]. Next, (b) obtaining a 2-D filter ***LPP*** by performing the

operation: **LP*** X **LP**; wherein **LP*** is a column vector having the same entries as **LP** and ***LPP*** having dimensions given by: {2n+1, 2n+1}; and generating a 2-D countour plot therefor. Next, (c) designing a 1-D high pass filter **HP** such that: **HP** = [Y_{-m}, $Y_{-(m-1)}$, ... Y_0, ... Y_{m-1}, Y_m]. Next, (d) obtaining a 2-D filter ***HPP*** by performing the operation: **HP*** X **HP**; wherein **HP*** is a column vector having the same entries as **HP** and ***HPP*** having dimensions: {2m+1, 2m+1} and obtaining a 2-D contour plot therefor. Next, (e) repeating (c) through (d) until the 2-D contour plot of ***HPP*** overlaps the 2-D countour plot of ***LPP***. Next, (f) generating a 2-D filter ***ONE*** having the dimensions of that of ***HPP*** with the only non-zero entry of value 1 located at the center of ***ONE***. Next, (g) creating matrix ***HPPinv*** by subtracting ***HPP*** from ***ONE***. Next, (h) convolving ***LPP*** with ***HPPinv*** to obtain ***DSCRN*** having dimensions: {2m+2n+1, 2m+2n+1}; and obtaining a 2-D contour plot therefor. Next, (i) repeating (a) through (h) until, by an examination of the 2-D contour plot of ***DSCRN***, an approximation to a desired circular symmetry is achieved.

BRIEF DESCRIPTION OF THE DRAWINGS

The preferred embodiments and other aspects of the invention will become apparent from the following detailed description of the invention when read in conjunction with the accompanying drawings which are provided for the purpose of describing embodiments of the invention and not for limiting same, in which:

Figure 1 shows the contour plot of a 2-D low pass filter designed in accordance with the method of the present invention as two sequential separable 1-D filters plus a subtraction function.

DESCRIPTION OF THE SPECIFICATION

It should be understood at the onset hereof that one skilled in this particular field of the arts, specifically that of filter design, would readily understand the sum and substance of the method herein described sufficient to build the filter of the present invention. One skilled in this art would also find the countour plot of Fig.1 useful in this regard.

It should also be understood that it is not the two separable filters themselves that approximate the result. Rather, the approximation is obtained when the two separable filters are applied to data in a specific way described that the outcome thereof approximates the result achievable by the non-separable filter.

The method of the present invention entails the following:

1. Selecting a cut-off frequency and designing a 1-D low pass filter such that: **LP** = $[X_{-n}, X_{-(n-1)}, \ldots X_0, \ldots X_{n-1}, X_n]$.
2. Obtaining a 2-D separate filter by performing the matrix operation: **LP*** X **LP** = ***LPP***, wherein **LP*** is a column vector with the same entries as **LP**; and wherein ***LPP*** has dimensions given by: {2n+1, 2n+1}. A 2-D countour plot is generated therefrom.
3. Designing a 1-D high pass filter such that: **HP** = $[Y_{-m}, Y_{-(m-1)}, \ldots Y_0, \ldots Y_{m-1}, Y_m]$.
4. Obtaining a 2-D filter by performing the matrix operation: **HP*** X **HP** = ***HPP***, wherein **HP*** is a column vector having the same entries as **HP**; and wherein ***HPP*** has dimensions given by: {2m+1, 2m+1}. A 2-D countour plot is generated therefrom.
5. Repeating steps 3 and 4 until the 2-D contour plot of ***HPP*** overlaps the 2-D countour plot of ***LPP***. Overlap as used herein means until the transition region of ***HPP*** overlaps the transition region of ***LPP***.
6. Generating a 2-D filter, ***ONE***, of dimensions of that of ***HPP*** with the only non-zero entry of value 1 positioned at the center of ***ONE***.
7. Creating matrix, ***HPPinv***, by subtracting ***HPP*** from ***ONE***
8. 8. Convolving ***LPP*** with ***HPPinv*** to obtain therefrom ***DSCRN*** having dimensions given by: {2m+2n+1, 2m+2n+1}. A 2-D countour plot is generated therefrom.
9. Examining the 2-D contour plot of ***DSCRN*** and repeating 1 through 8 until an acceptable approximation to the desired circular symmetry is achieved. It should be understood that at (9) if the desired response was not yet achieved then go back to (1) and design a new ***LPP***. To get a new ***LPP***, a new ***LP*** needs

to be generated. Thereafter a new ***HPP*** is again generated until its response properly overlaps that of ***LPP***.

When implementing for a media processor such as that made by Equator Technologies or for a Very Long Instruction Word (VLIW) processor or for a Digital Signal Processor (DSP), one would descreen not by using the non-separable filer ***DSCRN*** but by first applying the separable filter ***LPP*** and saving that result as, for example, video_1. Then, applying the ***HPP*** filter to video_1 and saving that output as, for example, video_2. Then, video_2 would be subtracted from video_1 yielding the descreened output. In this sequence the two filters are both separable. While an examination of the contour plot of the filter DSCRN does give the answer, one could, of course, also apply DSCRN to image data and see if the filter is doing what is desired

While particular embodiments have been described, alternatives, modifications, variations, improvements, and substantial equivalents that are or may be presently unforeseen may arise to applicants or others skilled in the art. Accordingly, the appended claims as filed and as they may be amended are intended to embrace all such alternatives, modifications variations, improvements, and substantial equivalents.